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TECHNICAL PROGRESS REPORT NO. 11 APRIL-JUNE 1995

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CE Inc. Contract 10392

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TECHNICAL PROGRESS REPORT NO. 11 APRIL-JUNE 1995

U.S. DEPARTMENT OF ENERGY

PITTSBURGH ENERGY TECHNOLOGY CENTER

CONTRACT DE-AC22-92PC92159

FOR

ENGINEERING DEVELOPMENT OF ADVANCED COAL-FIRED

LOW-EMISSION BOILER SYSTEMS

SUBMITTED BY:

ABB POWER PLANT LABORATORIES
COMBUSTION ENGINEERING, INC.

1000 PROSPECT HILL ROAD

P.O. BOX 500

WINDSOR, CONNECTICUT 06095-0500

AUGUST 30, 1995

DISCLAIMER

PATENT STATUS

Cleared by Chicago OIPC August 1, 1995.

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APPENDIX B Technical Paper: "Pushing the Pulverized Coal Envelope With LEBS" presented July 12, 1995 at the Eleventh Annual Coal Preparation, Utilization, and Environmental Control contractors Conference. Conf. paper removed for separate cycling. dt

EXECUTIVE SUMMARY

INTRODUCTION

The Pittsburgh Energy Technology Center of the U.S. Department of Energy (DOE) has contracted with Combustion Engineering, Inc. (ABB CE) to perform work on the "Engineering Development of Advanced Coal-Fired Low-Emission Boiler Systems" Project and has authorized ABB CE to complete Phase I on a cost-reimbursable basis and Phases II and III on a cost-share basis.

The overall objective of the Project is the expedited commercialization of advanced coal-fired low-emission boiler systems. The specified primary objectives are:

- NO_X emissions not greater than one-third NSPS.
- SO_X emissions not greater than one-third NSPS.
- Particulate emissions not greater than one-half NSPS.

The specific secondary objectives are:

- Improved ash disposability and reduced waste generation.
- Reduced air toxics emissions.
- Increased generating efficiency.

The final deliverables are a design data base that will allow future coal-fired power plants to meet the stated objectives and a preliminary design of a Commercial Generation Unit.

The work in Phase I covered a 24-month period and included system analysis, RD&T Plan formulation, component definition, and preliminary Commercial Generating Unit (CGU) design.

Phase II will cover a 15-month period and will include preliminary Proof-of-Concept Test Facility (POCTF) design and subsystem testing.

Phase III will cover a 9-month period and will produce a revised CGU design and a revised POCTF design, cost estimate and a test plan.

Phase IV, the final Phase, will cover a 36-month period and will include POCTF detailed design, construction, testing, and evaluation.

The Project will be managed by ABB CE as the contractor and the work will be accomplished and/or guided by this contractor and the following team members:

- DOE Contracting Officer's Representative (COR)
- Subcontractors
  - ABB Combustion Engineering Systems (ABB CES)
  - ABB Environmental Systems, Inc. (ABBES)
  - Raytheon Engineers and Constructors, Inc. (RE&C)
- Consultants
  - Dr. Janos Beér, MIT and Dr. Jon McGowan, U. of Mass.
- Advisors
  - Association of Edison Illuminating Companies - Power Generation Committee (AEIC)
  - Advanced Energy Systems Corporation (AES)
  - Black Beauty Coal Company
  - Electric Power Research Institute (EPRI)
  - Illinois Clean Coal Institute (ICCI)
  - Peridot Chemicals, Inc.
  - Richmond Power & Light (RP&L)
  - Southern Company Services, Inc. (SCS)

SUMMARY

The project is under budget and it is anticipated that Contract Item .002 (Phases II plus III) will be completed on schedule, although there will be some delays in Phase II due to funding limitations and changes in test site locations. The current status is shown in the Milestone Schedule Report included as Appendix A.

Technology Transfer activities included delivering a technical paper to the PETC "Contractors" Conference, finalizing plans for a Combustion 2000 Session at the '95 IJPGC, and submitting technical papers for two other conferences.

The ABB Team improved its emissions and efficiency objectives significantly.

ABBES and Southern Company Services are developing an agreement for Task 7 - CeraNO_X filter testing at Alabama Power - Plant Miller. Materials for the test apparatus will be ordered shortly. Laboratory testing of pressure drop characteristics is encouraging.

CFD modeling of variations in the low-NO_X firing system followed by testing in the Fundamental Scale Burner Facility indicate that improvements in performance and cost are likely. The redesign and procurement activities for testing the most promising variations in the Boiler Simulation Facility were started.

The POCTF licensing work is progressing well. The Environmental Information Document for PETC's NEPA activities was completed and the Indiana Department of Environmental Management responded to our list of formal questions, thus defining direction of our licensing work. A study to evaluate use of a Kalina cycle for the POCTF was initiated.

Plans for the next quarter include initiating CeraNO_X filter field tests, completing the evaluation of a Kalina cycle for the POCTF, resuming POCTF design work and initiating Task 11 low-NO_X firing system testing.

TASK 1 - PROJECT PLANNING AND MANAGEMENT

All work in Task 1 and all Task 1 deliverables for the reporting period were completed on schedule. All monthly Status, Summary, Milestone Schedule, and Cost Management Reports were submitted on schedule. A revised Phase IV cost estimate was submitted.

Regarding the schedule for Contract Item .002 (Phases II and III), several testing activities are behind schedule but this situation will not affect the completion date of Phase III or the Phase III deliverables, *i.e.*, the updated CGU and POCTF preliminary designs and the POCTF Test Plan. The testing activities which are behind schedule are CeraNO$_X$ filter testing (Tasks 7, 10 and 11) and Low-NO$_X$ Firing System testing (Task 11). The delays have resulted from a combination of funding limitations and changes in test site locations dictated by the host utilities.

A Project Review Meeting was held at Richmond Power & Light. DOE, RP&L, ABB PPL, ABBES and Black Beauty Coal Co. attended. The management and technical status were presented and discussed. There were no issues requiring follow-up. It was agreed that Black Beauty Coal Co. will be added to the Team as an advisor.

Technology Transfer activities consisted of the following:

- Delivered a LEBS paper at the Eleventh Annual Coal Preparation, Utilization, and Environmental Control Contractors Conference entitled "Pushing the Pulverized Coal Envelope With LEBS". A copy of the paper is included as Appendix B.
- Finalized plans for the Technical Session - "DOE's Combustion 2000 Program - LEBS and HIPPS" at the 1995 IJPGC.
- Submitted a technical paper entitled "Development and Design of an Advanced Pulverized Coal-Fired System" to the Twelfth Annual International Pittsburgh Coal Conference.
- Submitted a technical paper entitled "Improving Pulverized Coal Plant Performance" to the 1995 IJPCG.

As noted in the paper in Appendix B, ABB has reduced its emissions targets and raised its efficiency target as follows:

SO_2	lb/mm Btu*	0.10
NO_X	lb/mm Btu	0.02
Particulate	lb/mm Btu*	0.002
Net Efficiency (HHV)	%	45

* 3 lb S and 15.4 lb ash per million Btu in the coal.

The bases for these new targets are described in the paper.

TASK 7 - COMPONENT DEVELOPMENT AND OPTIMIZATION

SNO_X™ Hot Process

The Draft Task 7 Test Plan for CeraNO_X filter testing was completed.

The housing design has been finalized so that the skid layout can be assembled. Components such as duct heaters, flow measurement device, blower, and downstream NO_X and NH_3 analytical instruments have been selected and will be ordered during the next quarter.

A written proposal has been received from Southern Research Institute for: (1) setting up the upstream continuous NO_X measurement, (2) the feedback control system for NH_3 injection and (3) analytical measurements for particulates, NH_3 and NO_X in the inlet flue gas and particulates, NH_3, NO_X, SO_2, SO_3, and N_2O in the outlet flue gas. A verbal quote was received from Birmingham Industrial for piping and electrical work as well as a small enclosure at the test site for personnel and control equipment. The purchase orders will be finalized for these subcontracts shortly.

Engelhard Corporation has been developing the NO_X SCR catalyst for CeraMem's filter support. CeraMem fabricated test samples which were sent to Engelhard for evaluations. Based on CeraMem's measured gas flow pressure drop of 2.4" w.g. at 4 ft/min under ambient conditions and Engelhard's best catalyst on 100 cpi filters, it was estimated that the pressure drop through the catalytic filters may range between 4 to 7" w.g. at NO_X SCR operating conditions. Also, based on a meeting held at Engelhard on April 17 with CeraMem and ABBES, the variable test ranges for Engelhard's internal tests were defined. These are outlined in the following table.

VARIABLE	BASE CASE	RANGE
NO_X Conc.	200 ppm	75-400 ppm
Temperature	675,775,840°F	675,775,840°F
Face Velocity	2 ft/min	2-6 ft/min
NH_3/NO_X Ratio	1.0	0.75-1.1
O_2 Conc.	10%	4-10%
H_2O Conc.	10%	8-10%

Alabama Power Company notified the project team that Plant Miller will be available for Task 7 development work. Due to some changes in the exact site location, the schedule of the project has been delayed. Parametric testing is scheduled to start September 1, 1995. CeraMem has added an R&D program manager to their staff who will be assigned to the LEBS project to help maintain the schedule.

Low-NO_X Firing System

The overall objective is to develop an advanced firing system which reduces the NO_X emission levels leaving the primary furnace to 0.10 lb / MM Btu or lower while maintaining carbon in ash at 5% or less. Included in this scope is an integrated effort combining Computational Modeling, fundamental scale evaluation of firing system concepts performed in the Fundamental Scale Burner Facility (FSBF), characterization of the pulverizer system performance utilizing the Pulverizer Development Facility (PDF), and pilot scale testing of the firing system in the Boiler Simulation Facility (BSF).

Computational Modeling: Computational Fluid Dynamic (CFD) modeling of six (6) different firing arrangements in the Boiler Simulation Facility (BSF) has been completed using FLUENT V4.31. Included in these arrangements are several variations of the TFS 2000™ configuration. The objective of these simulations is to assess the impact of horizontally staged firing arrangements on the furnace aerodynamics and emissions reduction potential.

Post processing routines, including stoichiometry (bulk and along particle trajectory), mixing, furnace swirl, temperature, gas species, and furnace heat flux distribution, were performed and the results plotted. The results from each of the firing arrangements have been compared to the TFS 2000™ simulation. Based on the analysis to date these arrangements appear to be viable. (Refer to Figures 1-4 which show gas temperatures and oxygen concentrations at the horizontal furnace outlet plane.) Specifically, by the time the gas flows approach the horizontal furnace outlet plane, the predicted temperature and oxygen concentration for configuration BSF2, shown in Figures 1 and 2, are comparable to the TFS 2000™ arrangement, shown in Figures 3 and 4. In addition, these simulations have shown no impact on the relative levels of unburned carbon, compared to the TFS 2000™ arrangement. Further analysis and documentation of these simulations will be completed during the next reporting period, with subsequent recommendations for upcoming BSF testing. Additionally, two (2) more simulations have been set up. These simulations are currently underway and will be evaluated once the solutions have converged. The results will be documented in the report for the next reporting period.

Advanced Fuel Staging / Coal Reburn: During the reporting period, LEBS-related ABB-funded research activities were performed to further explore the impact of various vertically staged main burner region arrangements on both furnace emissions and carbon loss. This work was performed in the small pilot scale (6.1 MM Btu/hr) Fundamental Scale Burner Facility (FSBF), as was the previous advanced fuel staging testing. For this work, the FSBF was configured in a tangential firing mode with three elevations of coal and four elevations of auxiliary air comprising the main burner region, and up to four levels of separated overfire air available to model various globally air staged furnace configurations (Figure 5). A cleaned Illinois #6 coal ground to 90% minus 200 mesh, which was also fired during the prior fuel staging testing, was utilized for this work.

Results from this testing will be combined with those from previous FSBF work, and related modeling activities, to assist in the set up and design of large pilot scale testing (50 MM Btu/hr), which is now scheduled to occur in the Boiler Simulation (BSF) late in the next reporting period.

This latest FSBF test series provided preliminary characterization of the performance of the present NO_X control subsystem design, TFS 2000™, with the LEBS Illinois #6 coal. Under modeled TFS 2000™ operating conditions NO_X emissions from the FSBF testing were found to be approximately 70% lower than comparable baseline (no OFA) levels. Carbon conversion efficiency was similar for both cases (Figure 6). These results are consistent with present, large scale TFS 2000™ operating experience/ expectations, and LEBS project objectives. Further, large scale BSF combustion testing will provide additional quantitative information with respect to the design of the NO_X control subsystem performance for a LEBS design coal.

Additional FSBF combustion testing characterized the effect of stoichiometry on NO_X emissions for the Illinois #6 coal (Figure 7). This information has been used to size the air nozzles (auxiliary and overfire air) for the testing planned under Task 11 for proper air flow splits. (See below).

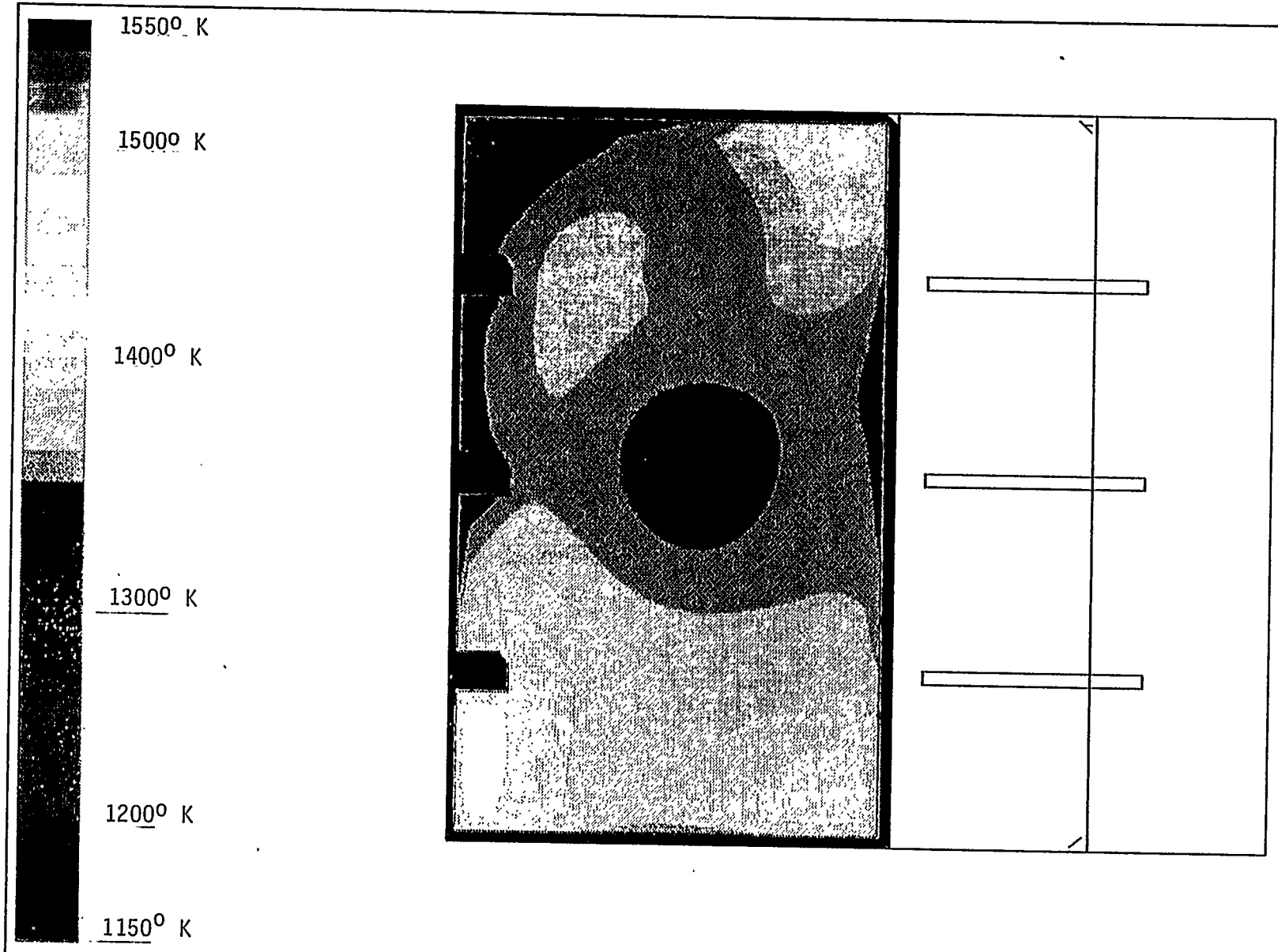
In addition to the testing of TFS 2000™ on a LEBS design coal, modifications to this system were tested to both further reduce NO_X emissions over those of the present system configuration while at the same time examining means of reducing the installed costs of this system. Toward this end, various main windbox staging scenarios were explored in the FSBF to quantify the impact of the bulk stoichiometry build-up in the main burner zone on final NO_X levels. This work built upon related LEBS project testing performed as part of the advanced fuel staged FSBF testing. Results of this work show that by suitably controlling the peak stoichiometry levels reached in the main burner region, final NO_X levels can be reduced as compared to "uncontrolled" cases. Further testing of staged main windbox configurations are planned for the upcoming BSF testing to verify these initial results.

Coal Pulverization: Primary emphasis during the reporting period was on Computational Fluid Dynamic (CFD) modeling of the pulverizer and classifier. The objective was to use CFD to develop a better understanding of the phenomenon controlling particle separation and demonstrate that CFD can be used to assist in parametric evaluation of classifier designs. Results from this CFD modeling indicate that the primary mechanism of particle separation in dynamic classifiers is particle impact on the blades. Aerodynamics are important in the region close to the blades, but the classifier does not induce large scale swirling flow in the pulverizer, as had been previously assumed.

The CFD models were shown to be capable of generating data with characteristics similar to experimental results (Figure 8) and has created confidence that CFD can be used to assist in parametric evaluations of classifier designs. The CFD classifier model is currently being used to validate rotor designs for a full size utility unit. Additionally, a CFD model of the lower pulverizer was developed to provide an understanding of flow in the lower

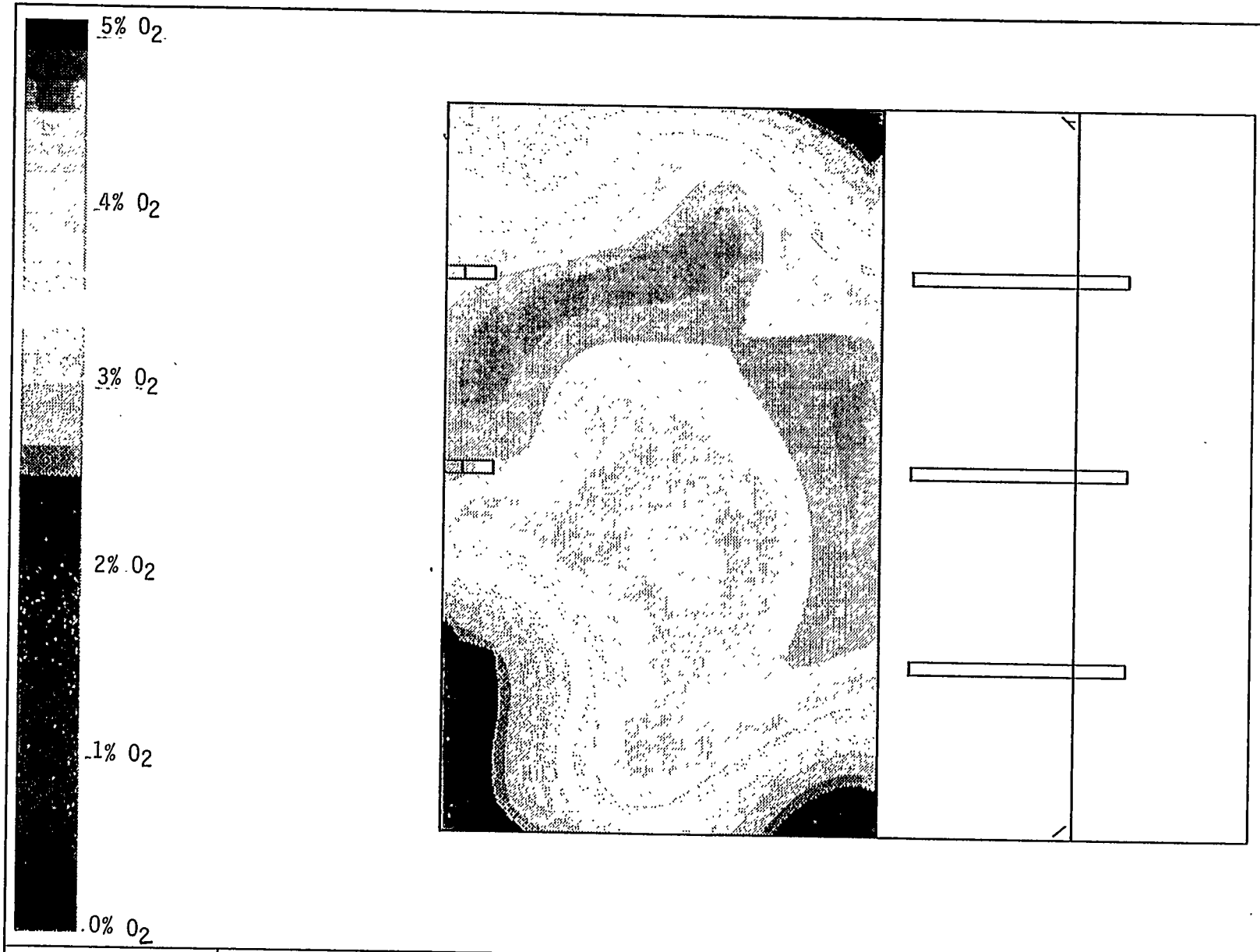
half of the pulverizer. The results of this model are being used to provide better input information to the classifier models.

A Classifier Test Facility was designed and components fabricated. This facility will be used in the next reporting period to provide information on the recycle rate of various classifier concepts, which is critical to overall pulverizer power requirements and capacity.



	BSF 2 (MOD FUEL AIR DISTR) Temperature (K)	May 24 1995 Fluent 4.31 Fluent Inc.

Figure 1

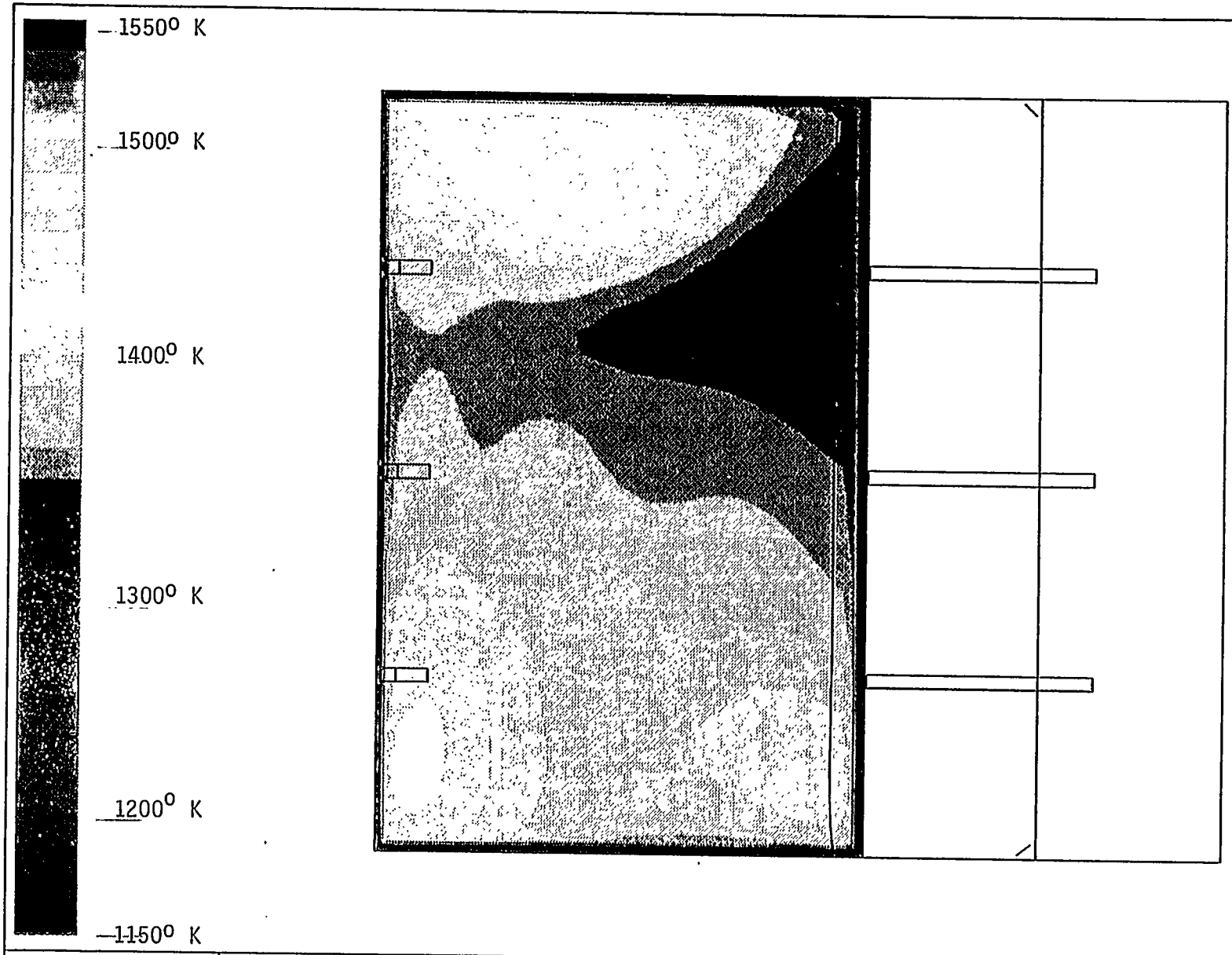


BSF 2 (MOD FUEL AIR DISTR)

O2 Mole Fraction

May 24 1995
Fluent 4.31
Fluent Inc.

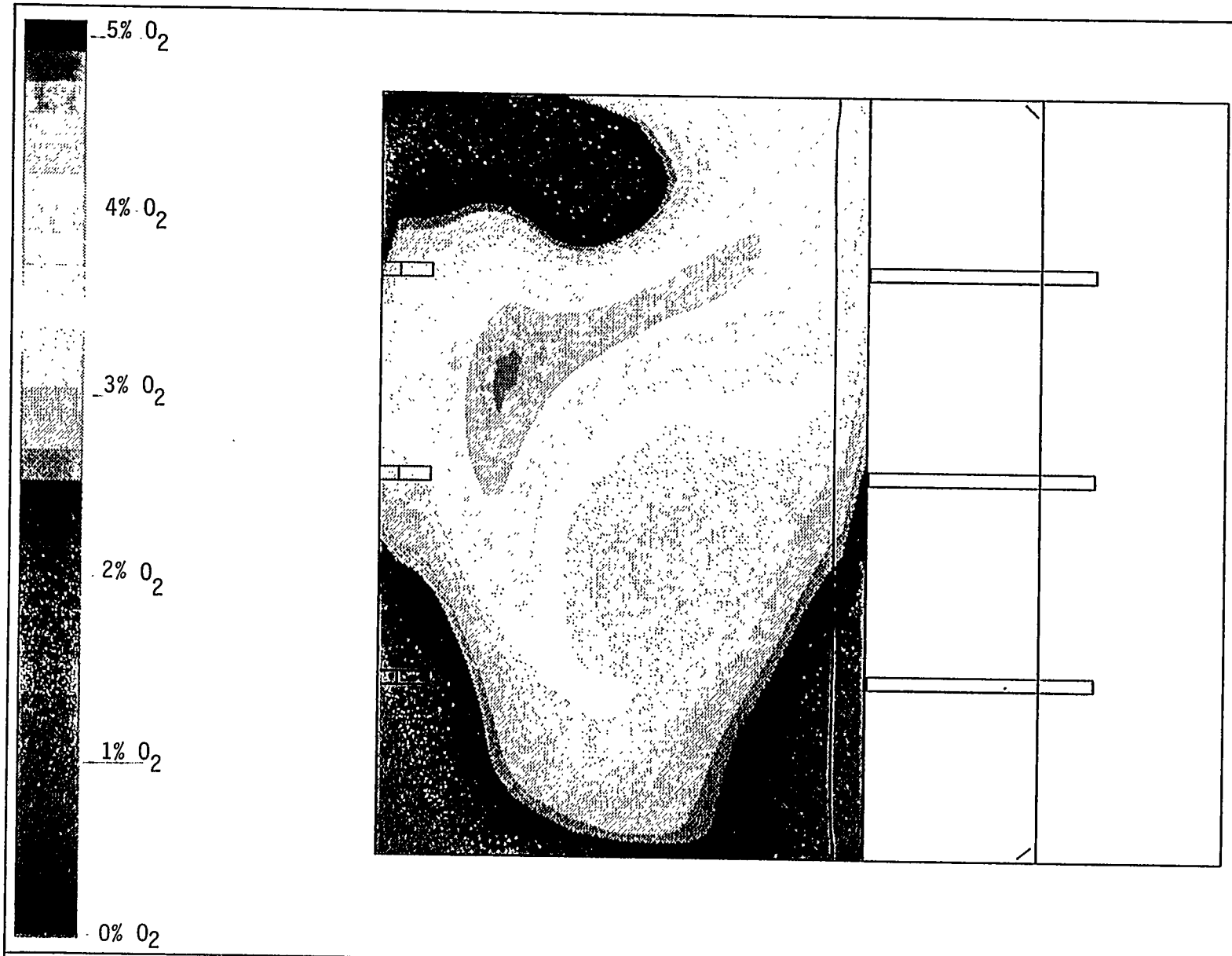
Figure 2



BSF TFS-2000
Temperature (K)

May 25 1995
Fluent 4.31
Fluent Inc.

Figure 3



BSF TFS-2000
O2 Mole Fraction

May 25 1995
Fluent 4.31
Fluent Inc.

Figure 4

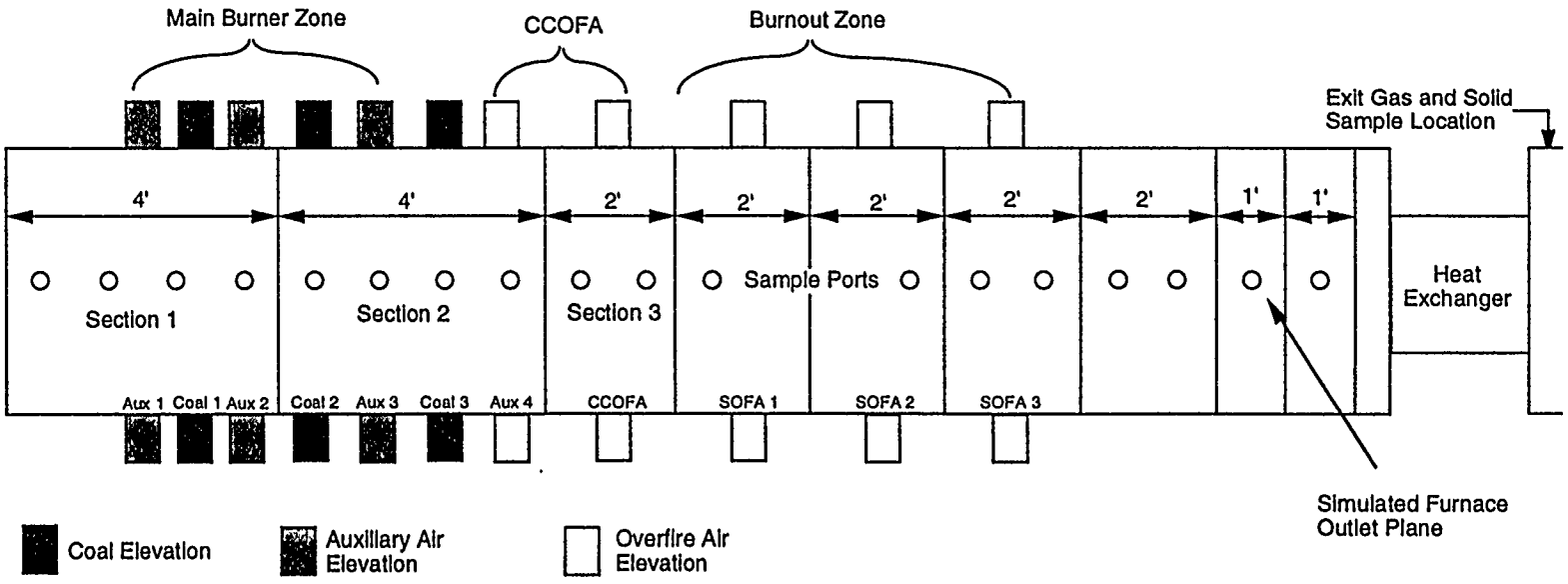


Figure 5 - Schematic of Fundamental Scale Burner Facility

Figure 6 - **Baseline versus TFS 2000™ Firing System Data**
FSBF Combustion Testing, 6.1 MMBtu/hr
Illinois #6 Coal

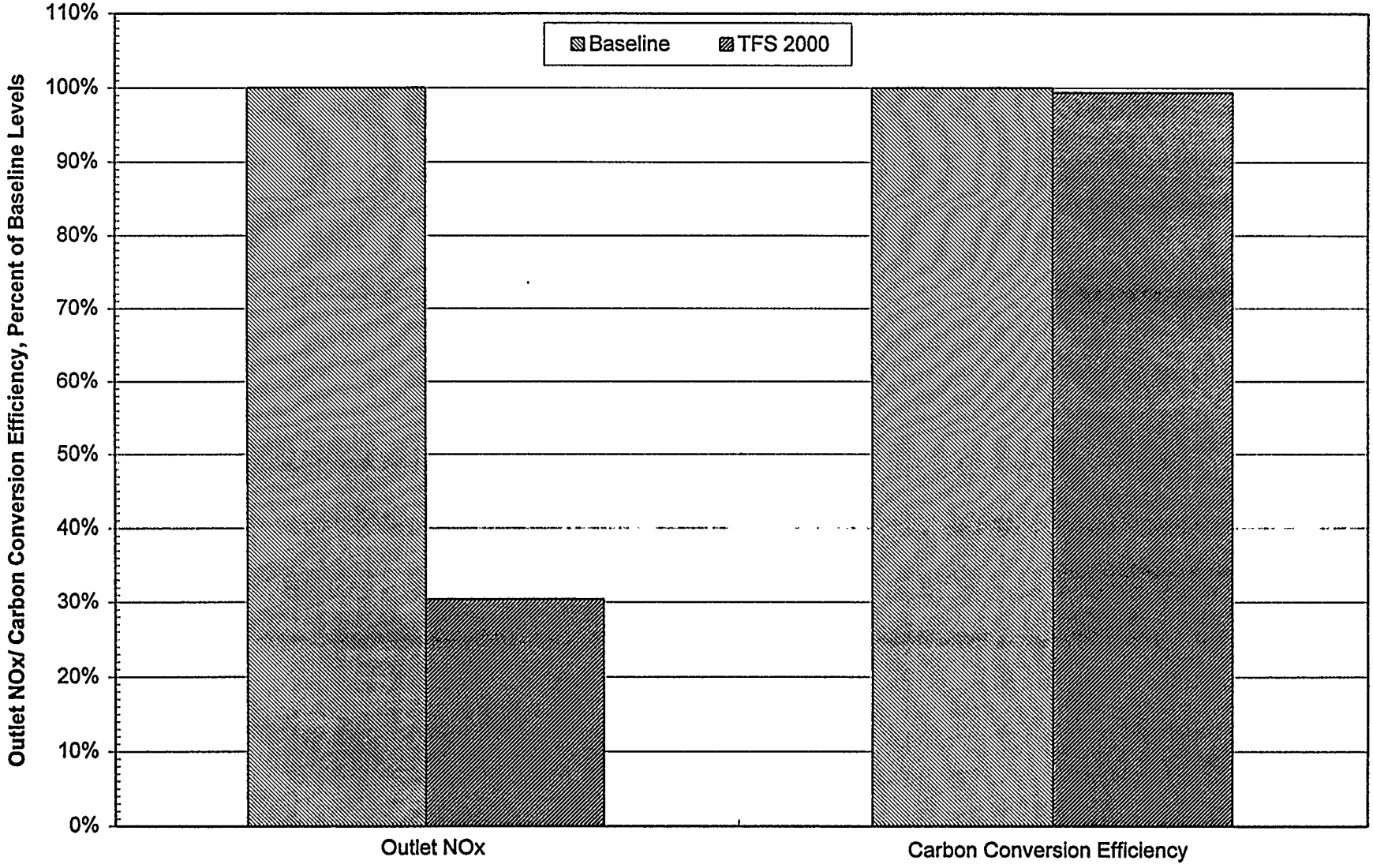


Figure 7 - **NOx versus Main Burner Zone Stoichiometry**

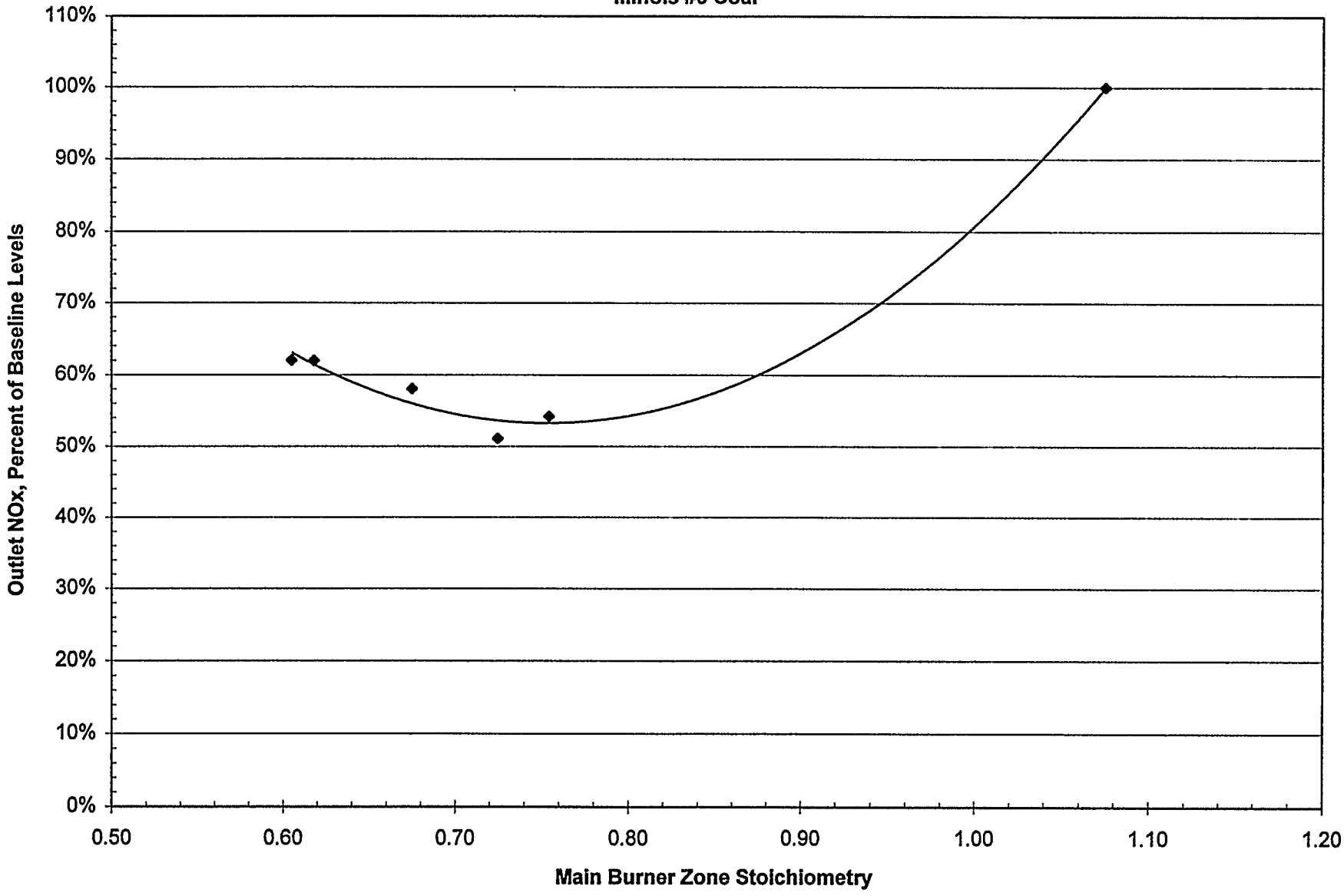
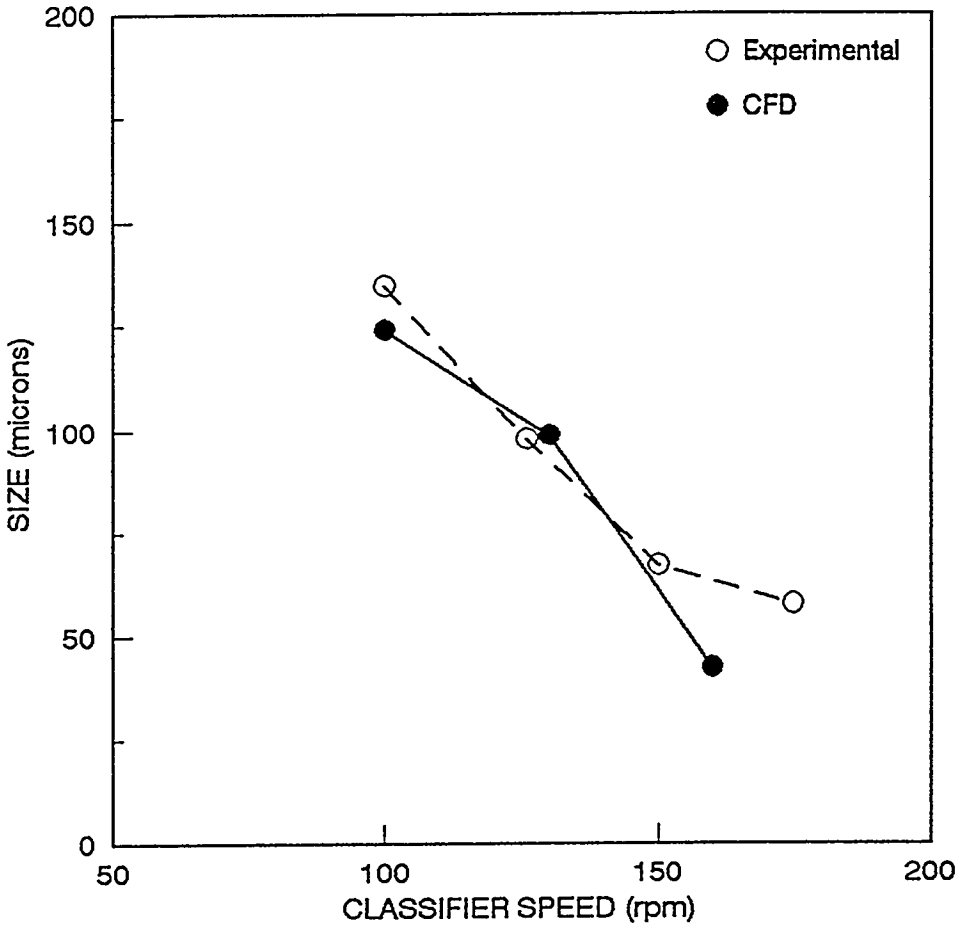


Figure 8 - EXPERIMENTAL AND CFD RESULTS vs CLASSIFIER SPEED
HP2 DYNAMIC CLASSIFIER



Definitions of "Size"

Experimental: 90% by weight of the material exiting the mill is below this particle size.

CFD: Represents the mean size of particles exiting the mill, weighted by the number of particles in each size class.

TASK 8 - PRELIMINARY POC TEST FACILITY DESIGN

Site Selection

In October 1994 ABB CE formally accepted the Richmond Power & Light offer of Whitewater Valley Unit No. 1 as the host site for the Proof-of-Concept Test Facility.

Preliminary Design

For budget reasons the design work was placed on hold until August. ABB recently acquired rights to Kalina cycle technology and met first with Richmond Power & Light and then with DOE to discuss integrating this technology into ABB's current LEBS configuration. All parties agreed to this addition and the Work Plan was supplemented accordingly.

The first step will be to evaluate application of a Kalina Cycle in the POCTF at Richmond Power & light. This study will be funded fully by ABB. Following completion of this study, POCTF preliminary design work will be restarted. The Task 8 schedule will be delayed approximately one month due to the addition of this study. However, the Phase II completion date of March 31, 1996 will not be affected.

Licensing

The licensing work achieved a milestone with completion of the Environmental Information Document, which constitutes one of the submissions for the National Environmental Policy Act of 1970 (NEPA). The document will be presented to DOE/PETC at the appropriate time. To date, two documents have been prepared to respond to POCTF NEPA requirements.

- the DOE Environmental Questionnaire, and
- the Environmental Information Document

It is anticipated that these two documents will provide sufficient project information to DOE/PETC to meet NEPA compliance.

As reported last quarter, a formal letter was submitted to the Indiana Department of Environmental Management (IDEM), requesting their clarification and guidance on six key licensing issues. Late in the present reporting period a response was received from IDEM. Although this response is still under evaluation preliminary findings are that:

- preparation of a PSD permit application (prevention of significant deterioration of air quality) will be required for the sulfuric acid mist emissions,

- dispersion modeling of the sulfuric acid mist emissions will be required to support the PSD application, and
- sufficient overall direction was provided in the IDEM response so that licensing plans can be refined and licensing activities can proceed.

TASK 9 - SUBSYSTEM TEST DESIGN AND PLAN

SNO_X Hot Process

The Subtask 9.2 Test Plan was submitted to DOE for their approval/comments. The Plan will be finalized by adding details of the site and of information generated in Task 7. The Plan was submitted to CeraMem and Engelhard for their acknowledgments.

Public Service Colorado notified the LEBS project team that they are no longer willing to host the pilot-scale development work and discussions with PSC-Colorado to request a reconsideration were fruitless. The project team visited Richmond Power & Light-Whitewater Valley and has identified a site at that station which might be available. Alabama Power Company has also been approached about hosting the pilot-scale system. To date, they have not committed but indicated that this would be possible. At the close of this reporting period, a Task 11 site has not been identified.

CeraMem has determined the structural capacity of the pilot-scale test facility housing and determined what modification must be performed to meet process condition requirements. Long lead time equipment has been identified and initial specifications have been developed.

Low-NO_X Firing System

Completed in previous reporting period.

SNO$_X$ Hot Process

An Environmental Questionnaire (NEPA) for the PSC-Comanche site was prepared and submitted in early May. However, recent developments have rendered this document unusable and it will be replaced once a replacement site for Task 11 testing has been identified.

CeraMem has commenced specifying the equipment, starting with the housing. CeraMem has contacted the housing fabricator and received pressure ratings for the housing at both 800 and 850°F.

Task 10 (and most likely Task 11) will finish behind schedule. However, the overall Phase II & III work scope will be completed within the required 24-month schedule.

Low-NO$_X$ Firing System

Preparation of ABB's Boiler Simulation Facility (BSF) for upcoming Task 11 NO$_X$ control subsystem testing was initiated during this period. This work will support the large pilot scale testing (50 MM Btu/hr) of the presently selected NO$_X$ control subsystem and potential enhancements. This testing is currently scheduled to be performed late in the next reporting period. To date BSF preparation has focused on design and installation of components necessary for control of both global and main burner region stoichiometry. This added capability will be combined with individual main windbox secondary air flow measurement devices to allow for the testing of various staged firing system configurations within the BSF. Completed work to date includes the installation of electronically controlled dampers for the main windbox flows and the writing of algorithms necessary to perform the automatic stoichiometry control. Installation of conduit, wiring, and sensors has also been initiated.

In addition to the control system modifications, firing system design activities were begun. Both auxiliary air and low NO$_X$ coal nozzle tip designs have been completed and sent out for multiple bids prior to the initiation of construction. Two different free area auxiliary air nozzles have been designed, which permits maintaining design secondary air velocities over a range of desired main burner region stoichiometries. All auxiliary air compartments will have variable yaw/ variable tilt capability to allow for broad changes to be made in the fireball aerodynamics in order to control and test varied bulk mixing and flow pattern scenarios and their impact on firing system performance.

PLANS FOR NEXT QUARTER

Initiate preparation of the annual update of all Plans.

Submit an abstract of a technical paper for the 21st International Technical Conference on Coal Utilization & Fuel Systems.

Continue Task 7 work.

Continue Task 8 licensing work, complete evaluation of a Kalina cycle for the POCTF and resume work on the preliminary design.

Continue Task 10 work.

Initiate Task 11 work.

APPENDIX A - 2 pages

DOE F1332.3
(11-84)

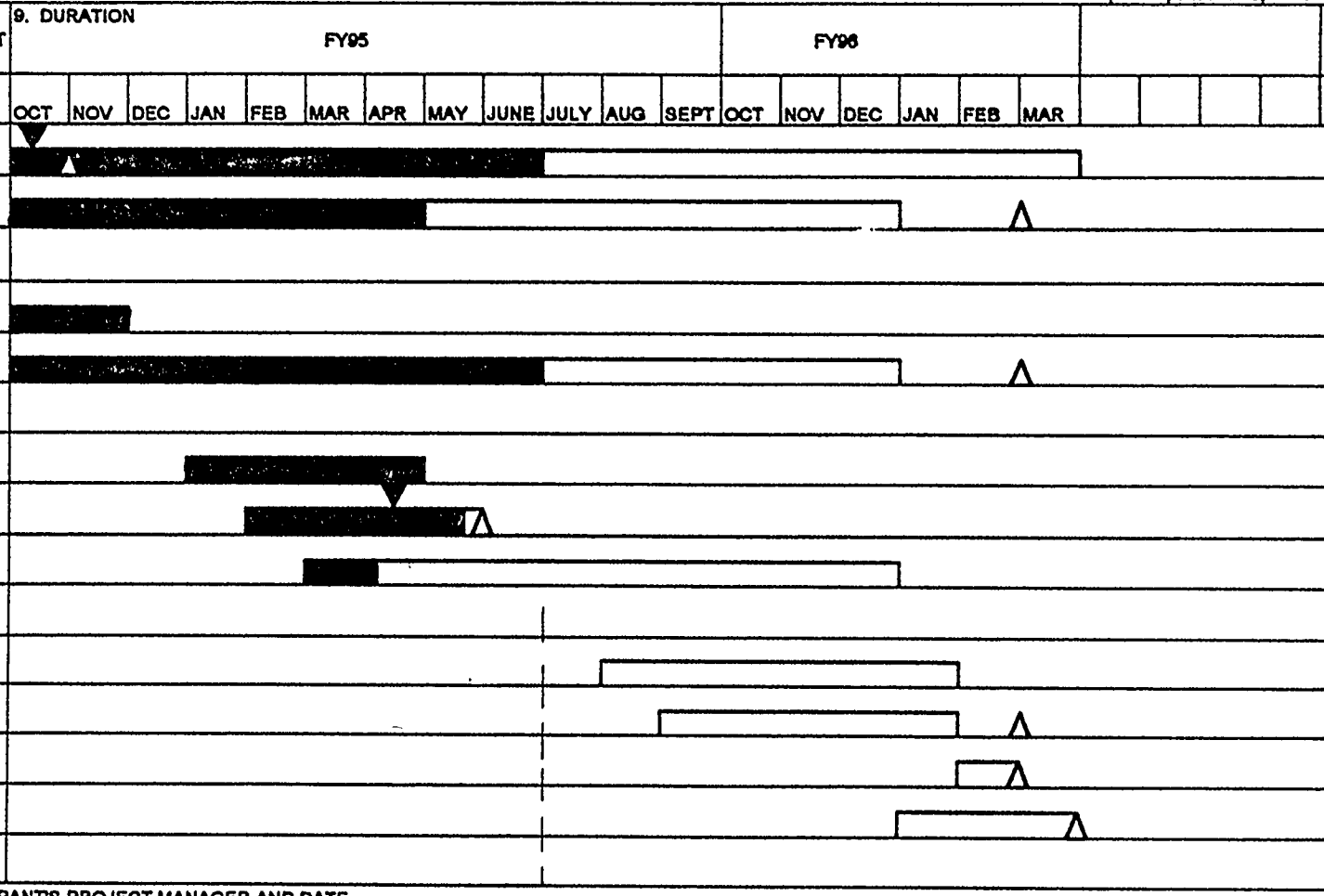
U.S. DEPARTMENT OF ENERGY

MILESTONE SCHEDULE ☒ PLAN ☒ STATUS REPORT

FORM APPROVED
OMB 1901-1400

1. TITLE	2. REPORTING PERIOD	3. IDENTIFICATION NUMBER
Engineering Development of Advanced Coal-Fired Low-Emission Boiler Systems - Phases II & III	Oct. 1, 1994 - June 30, 1995	DE-AC22-92PC92159

4. PARTICIPANT NAME AND ADDRESS	5. START DATE	6. COMPLETION DATE
Combustion Engineering, Inc. P.O. Box 500 Windsor, CT 06095-0500	October 1, 1994	September 30, 1996



7. ELEMENT CODE	8. REPORTING ELEMENT	10. PERCENT COMPLETE PLAN	10. PERCENT COMPLETE ACTUAL
	PHASE II		
1.0	Prj Mgt	38	38
7.0	Comp Dev	57	45
8.0	POCTF		
8.1	Site Sel	100	100
8.2	Pre Dsn	37	36
9.0	Subsyst		
9.1	Design	100	100
9.2	Plan	100	95
10.0	Constr	51	11
11.0	Subsyst		
11.1	Oper	0	0
11.2	Test Ev	0	0
11.3	Dsn Ev	0	0
12.0	Draft Report	0	0

11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE

John W. Regan JULY 10, 1995

U.S. DEPARTMENT OF ENERGY

DOE F1332.3
(11-84)

MILESTONE SCHEDULE ☒ PLAN ☐ STATUS REPORT

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Engineering Development of Advanced Coal-Fired Low-Emission Boiler Systems - Phases II & III		DE-AC22-92PC92159
4. PARTICIPANT NAME AND ADDRESS Combustion Engineering, Inc. P.O. Box 500 Windsor, CT 06095-0500		5. START DATE October 1, 1994 6. COMPLETION DATE September 30, 1996

7. ELEMENT CODE	8. REPORTING ELEMENT	9. DURATION FY96																						FY	FY	10. PERCENT COMPLETE	
	PHASE III	APR		MAY		JUNE		JULY		AUG		SEPT														Plan	Actual
1.0	Prj Mgt																										
13.0	CGU Dsn																										
14.0	POCTF																										
14.1	Rev Dsn																										
14.2	Test Plan																										
15.0	Report																										

11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE

APPENDIX B - 14 pages